AD NUMBER

AD843846

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AUTHORITY

SMUFD, per d/a ltr dtd 8 Feb 1972

TRANSLATION NO. 898

DATE: Mar 1963

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DEPARTMENT OF THE ARMY
Fort Detrick
Frederick, Maryland

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PRELIMINARY GUIDE LINES FOR TESTING FILTERS FOR THE REMOVAL OF SUSPENDED SUBSTANCES FROM AIR AND OTHER GASES (INCLUDING RADIOACTIVE DUSTS, MISTS, BACTERIA AND VIRUSES)

/Following is the translation of an unsigned article in the German-language periodical Staub (Dust), Vol. 23, No. 1, January 1963, pages 21-27, special reprinted, published by the Dust Research Institute of the Main Association of the Industrial Trade Unions, Inc., Bonn.7

## 1. General Remarks

### 1.1. Definition

Filters for removing suspended substances will be termed "dust" filters. Dust filters for respiration do not fall into this category.

"Dust" filters, in particular "dust" filters of special type S, are understood to be filters which show particularly high eliminating efficiency towards stable and fluid aerosols of all particle sizes. Their main application is for substances whose particle diameter is below 1 $\mu$m. Dust filters of special type S are often mistakenly designated as "absolute filters."

### 1.2. Technical Prerequisites for Use of the Filter

"Dust filters of special type S must retain from the gas or gas mixture to be purified the stable and fluid suspended substances, bacteria and viruses to an optimum percentage. They are generally utilized as final filters in multistage combinations in which the preliminary stages may be fibers, fleece, knits or weaves (1), as well as traps of different construction and mode of operation (2) or other "dust" filters. The high efficiency of the special type "dust" filter with the finest suspended particles demands an extremely close fit between the filter element (e.g. compartment) and the housing, frame, etc. for satisfactory operation.

If the filter unit consists of non-regenerating elements, the filter must be easily and safely replaceable. Flow resistance of the unit must be continually measurable. Special Type S filters should be changed generally when their flow resistance has doubled to tripled the starting resistance. Manufacturers' recommended changes should be adhered to. The time for change of the filter is also determined by a loss in the efficiency of ventilators or fans present in the system. In all instances in which uniform air change or air quantities are important (e.g. in nuclear installations, isotope labs, certain hospital rooms) adjustable ventilators or low and high pressure generators with excellent characteristics must be used. Filters of suitable construction (see 1.4.) are used corresponding to the type of suspended matter (e.g. acid fumes, pyrophoric dusts, bacteria, etc.) as well as temperature and moisture contents of the gas or gas mixture to be filtered.

## 1.3. Service Life

Stability of design and therewith service life of the type S filter is determined by the type and particle size distribution of the materials to be filtered as well as by the quality of the preliminary filters. It is therefore difficult to correlate in practice the service life of a filter with the quantity of material eliminated. Since concentration, particle size distribution and type of dust as well as type of preliminary filters differ from installation to installation, it is not meaningful to carry out routine lab tests with regard to service life with test dust on special type S filters. These tests would have little or no practical value.

See also 1.2. for changing filters.

## 1.4. Types of Construction

The steadily growing demands of purified gases or gas mixtures in all phases of technology prompt installation of "dust" filters for the most complex problems of gas purification. Consequently so many types of construction and materials are available, that it is possible to list here only such examples of designs and types which are important to the outline. No pretense is made for a complete listing.

### 1.4.1. "Dust Filter of Type S, Specifically for Elimination of Bacteria and Viruses

Bacteria and viruses, if not attached to stable or fluid suspensions, have diameters of lengths of ca. 3 nm to 30 $\mu$m.

Depending on their size the same percentages are retained (on the filter) as other stable or fluid suspensions of corresponding size. They differ from other suspensions only in that under certain circumstances favoring formation of colonies and growth, "growing through" the filter may occur. This must be considered in the case of units which ventilate aseptic rooms (3).

According to type of maintenance, supervision of "Pure air" and frequency of change differentiation into the following groups is made:

a) Normal filters. Combustible and non-combustible types

b) Filters, which may be impregnated or sprayed with bacteriostatic materials. Combustible or non-combustible types.

c) Sterilizable filters (usually by hot steam), usually non-combustible.

In some instances the filters of groups a) to c) may be coupled with subsequent UV radiation units for pure air. High intensities and sufficiently lengthy illumination times are of decisive importance for effectiveness.

1.4.2. "Dust Filter Type S for Eliminating Radioactive and Other Suspensions

The multiple designs may be characterized by the following features.

1.4.2.1. Combustibility

There is differentiation between combustible, slow burning, fire sensitive, fire resistant, and incombustible filter elements (DIN 14011).

1.4.2.2. Operating Temperatures

Operating temperatures are chosen according to:

a) Materials of which the filter medium and spacer are manufactured.

b) The cement used in sealing and fasting the filter to fram of housing.

c) The frame materials.

The following divisions are made:

1) Operating temperature to 60° C. Filter medium frequently consists of plastics; frame of wood, plastic or specially treated heavy cardboard.

2) Operating temperature to 120° C. Filter medium frequently consists of cellulose or cellulose-asbestos fibers, or glass or glass-asbestos fibers; frame of plywood, frequently made rather incombustible by impregnation, or steel (cadmium).

3) Operating temperature to 430° C. Filter medium frequently consists of glass fibers or a mixture of glass and asbestos fibers. Frame of steel.

4) Operating temperature above 500° C. Filter medium frequently of quartz, ceramic or other mineral fibers. Also metallic, ceramic or mineral sintering body. Frame of metal or ceramic depending on temperature.

1.4.2.3. Sensitivity to Moisture

Certain filter materials are sensitive to moisture and lose their efficacy above a certain relative gas moisture. Unimpregnated cellulose or cellulose-asbestos filter media generally should only be used to a relative gas moisture of 85%. In any case the maximum relative gas moisture indicated by the manufacturer should not be exceeded.

1.4.2.4. Stability Towards Chemicals

Special Type S filters can be manufactured which by themselves or in combination with preliminary filters (e.g. washers, etc.) can handle practically all problems of normal and aggressive mists and dusts. In most instances "dust" filters are sensitive only to certain chemicals (e.g. solvents, hydrofluoric acid, etc.).

The manufacturers will give information.

1.4.2.5. Special Structural Designs

1.4.2.5.1. In nuclear technology it is rarely impossible to change filters or regenerate them in the course of a few years. Filters used in this technology must possess high elimination qualities in addition to long service life. So called "deep bed" filters among other methods have been found usable. These filters consist of thick layers of fibers of various diameters of deep sand layers connected to a "dust" filter of special Type S, all layers being usually combined into a single housing.

1.4.2.5.2. With great use of deep bed filters and other constructions the filters must contain structural characteristics which conduct the heat produced by this activity, to the outside. Frequently filter housing are cooled.

1.5 Flow Resistance

The widest application as special type S filter was found by the fiber filter. For the quantities of flow (50-2300 cu m/hr/compartment) adapted to the particular filter element, the resistance of new, unused filter elements lies between 10 and 5 mm WS (water column).

They may amount to 250 mm Hg for special constructions. The resistance of a unit depends on the availability of ventilators, fans and low pressure generators (see 1.2.) If the resistance of a filter is of commercial importance it can be considered so only in connection with other characteristics of the filter.

2. Testing of "Dust" Filters and Special Type S "Dust" Filters

2.1. Assumptions

### 2.1.1. General

Resistance and service life of a filter may be very important but the final criteria for the quality of the filter is its elimination characteristic or permeability in relation to particle size and in relation to deposit (flow-against and flow-through velocity). Equipment and methods are described below which measure elimination rate (or permeability) for various particle sizes, as well as flow resistance for "dust" filters. The methods described additionally permit studies on mechanical behavior on dust accumulation.

### 2.1.2. Definition of Elimination Rate, Permeability and Decontamination Factor

If the concentration of suspended matter in front of the filter amounts to $N_1$ and behind the filter to $N_2$, amount of deposit equals

$$\eta = \left(1 - \frac{N_2}{N_1}\right)$$

and percentage elimination rate

$$\eta = \left(1 - \frac{N_2}{N_1}\right) \cdot 100\%$$

In filters of highest efficacy, such as special type S filters, the convenient and distinct concept of permeability (D) is employed. Permeability (D) = $N_2/N_1$; or $D = 1 - \eta$; or percentage wise $(N_2/N_1) \cdot 100 = 100 - \eta\,(\%)$. In the case of suspended radioactive substances in the efficacy is sometimes described in terms of the decontamination factor (F). F is defined as $N_1/N_2$. If the decontamination factor is larger, permeability is smaller, and the amount of elimination larger. Accordingly elimination of 99.5% means permeability of 0.05% and a decontamination factor of $2 \cdot 10^3$.

### 2.1.3. Substantiation of Test Methods

Because the large elimination and negligible permeability of the stable and fluid suspended materials in all particle sizes, most test methods used for filters with negligible elimination fail, as they show practically 100% elimination, especially when efficacy is established by gravimetric methods. Special methods for testing special type S "dust" filters have therefore been developed, which are very similar to methods for testing "dust" filters of breathing devices (4).

Since "dust" filters show a relationship between permeability (minimum of elimination) and type and particle size of the dust as well as to flow velocity, the test must extend over a wide range of particle sizes. This range, from nm to $\mu$m, for technical reasons will be divided into overlapping but polydispersed sections.

Testing of "dust" filters by means of monodispersed aerosols (e.g. DOP-test method: particle diameter 0.3 $\mu$m) is of great importance for routine production checks of filter materials. Its behavior on velocity and particle size range is well known, but it is not sufficient for tests as to typing or control. Typing or control tests therefore are carried out by means of the following three stable or fluid "dust" types.

1. Testing of total filter elements with oil mist, in which all drops have a diameter of less than 1 $\mu$m and most of the particles lie between 0.3 and 0.5 $\mu$m.
2. Testing of segments of the filter element with natural atmospheric, but radioactively indicated aerosol. Diameter of "dusts": less than 0.3 $\mu$m to several nm.
3. Testing of segments of the filter element with freshly obtained quartz dust less than 10 $\mu$m diameter. 80% of the particles have a diameter of 0.5 to 2 $\mu$m.

## 2.2 Test Installation for Complete Filter Elements (e.g. Compartments)

### 2.2.1. Structural Design of the Equipment

Schematic description is given in Figure 1.

The equipment contains a heavy duty-centrifugal-ventilator with the following data:

| | |
|---|---|
| Rate of revolutions: | 2900 rpm |
| Air Intake: | 3000 cu m/hr |
| Total Pressure: | 160 mm WS |
| Power Consumption: | 1.6 kW |

The intake side of the ventilator is equipped with an intake nozzle with a circular measuring gauge to measure the flow through, independent of pressure (see 2.2.4.2.)

The following components, whose measurements may be read from the drawing, are connected to the pressure side of the ventilator:

1. Butterfly valve, air tight, with a graduated pointer valve.

2. Two intake probes to mix the oil testing mist, supplied by the mist generators.

3. Flow rectifier, consisting of two screens, each having mesh width of 4 mm. They are staggered by 45°.

4. Measuring tube with an unobstructed width of 250 mm diameter and a calibrated quarter turn nozzle set inside to measure flow through (see 2.2.4.1.). The measuring distance has a total length of 5250 mm (16 diameters in front and 5 diameters after the quarter turn nozzle).

5. A square diffuser, 1760 mm long, with inside dimension of 570 X 570 mm at its end, attached after a transition section. It is equipped with a 712 X 712 mm flange, against which the "dust" filters are pressed during their test. The flange is equipped above and below with two guide rods, to guide the counterpart necessary to hold the filter in position. A sampling device, with an inside diameter of 15 mm, to remove partial flow to measure concentration of untreated air is placed in this air diffuser at the 265 mm axis in front of the filter to be tested.

6. The pure air diffuser is mounted on the rolling cart, which at its wide end with 570 X 570 mm inside dimension is equipped with a flange similar to that of the untreated air diffuser. By bolting both frames together for the test an airtight seal is obtained. The pure air diffuser is 1300 mm long. The diameter tapers to 250 X 250 mm. This exhaust is equipped with an orifice of 187 mm diameter to stabilize the flow as well as to determine pure air concentration. An 8 mm diameter sampling device for removal of partial flow for pure air concentration measurement is placed 135 mm towards the inside from the exhaust.

7. Couplings of any sort may be attached to the frame of the untreated air diffuser, so that any desired filter elements may be connected as long as quantity of flow and resistance do not exceed the capacity of the ventilator of the test unit.

### 2.2.2. Preparation of the Oil Mist Used as Test Aerosol

Mist generators are used (manufacturer: Draegerwerk, Luebeck, Model VI) whose mode of operation is as follows (see Figure 2): an atomizing container (8), filled with a definite paraffin oil (technically pure; rosin and alkali free; density 0.853 g/cm$^3$ at 20° C; viscosity at 20° C 4--5 Engler degrees or 30-38 centistokes; flash point + 180° C; solidifying point - 14° C) is kept at the boiling point in a waterbath (9) by means of a heating coil (25). The atomizing vessel, shown separately at the upper right of the illustration, contains a nozzle assembly, which consists of a triangular arrangement of the individual atomizing nozzles. The nozzles have 0.4 mm bores and are chosen to develop mists of 13.5 l/min. by means of filtered compressed air [2.4 atmospheres excess pressure] from a manometer (14). Paraffin oil normally has very low vapor pressure. On the other hand it is known that when liquid is atomized, vapor pressure and volatization velocity increase with decreasing particle diameter. Atomizing takes place at 100° C. This temperature has a 3-fold effect:

1. A bath at the boiling point, which is a good thermostat, guarantees constant atomizing temperature.

2. At 100° all oils have lower viscosity; variability of viscosities found at low temperatures do not have a noticeable effect at 100° C.

3. At this temperature the finest fog particles atomize completely and the larger ones at least partially.

At the exhaust pipe, visible at the center and pointing diagonally upwards, leading over control vent (19) and spiral tube (20) to mixing container (4), a mixture of air, oil. vapor and mist is found. This is diluted with about 50 liter cold compressed air per minute in container (4) whereby condensation of the oil vapor occurs.

The aerosols formed comprise the chief portion of the mist. The mist leaving the unit is at a concentration of 3000 mg/cu.m. More or less oil mist may be supplied to the apparatus by 2-way valves. Since high concentration means larger chance of coagulation, and is impractical, work is usually carried out with a diluted mist-air mixture.

If new developments improve the efficiency of special type S filters, the work may be carried out at greater concentrations. As reported previously (6), the diameter of suspended oil drops is $< 1 \mu m$ the majority being between 0.3 and 0.5 $\mu m$.

## 2.2.3. Measurement of Elimination Rate (or Permeability)

The Tyndallometer (manufacturer: Leitz, Wetzler) employing a 30 Watt bulb, was used to determine unpurified and purified air concentrations (measurement of relative intensity of light scattered by the suspended particles). Flow portions of impure and purified air alternately are led through the sampling devices described in 2.2.1., so that for each minute of the test period the amount of elimination may be determined from the relative intensities obtained. The diameter of the sampling device equipped with a cutting edge and the cross section of both diffusers with that sampling device is chosen so that the adjusted partial flow removal through both samplers is equivalent per time unit. Test time is 20 minutes. The elimination rate is measured every minute. In the final test report the beginning elimination rate, the average rate for the test time, and the greatest and smallest elimination rate and matching permeability are reported. The average error of the average rate essentially depends on the quality and nature of the filter tested.

Example: A good "dust" filter of special type S; oil mist test of the complete filter element:

| | |
|---|---|
| average elimination rate: | 99.89 $\pm$ 0.01% |
| average permeability: | 0.11 $\pm$ 0.01% |

Filter with reduced efficiency

| | |
|---|---|
| average elimination rate: | 99.73 $\pm$ 0.03% |
| or average permeability: | 0.27 $\pm$ 0.03% |

## 2.2.4. Measurement of Flow Quantity

"Dust" filters of type S may be manufactured of various constructions and sizes. Consequently stress date for various filter elements may vary greatly. The test apparatus therefore contain two measuring devices to determine permeability.

2.2.4.1. The measuring tubes with quarter turn nozzle (ND 10; NW=LW 250) described in 2.2.1. are available for limits of 300 to 1500 cu m/hr. At an operating pressure of 300 mm WS and an operating temperature of 20° C at a flow of 1500 cu m/hr, effective pressure amounts to 16 mm WS. Upon calibration the following flow equation was obtained: $Q=375.21\sqrt{p}$, in which Q is in cu m/hr and in mm WS. The lower the rate of flow, the larger will be the error in the measuring arrangement. At 300 cu m/hr error amounts to 3% (VDI Rules for flow DIN 1952). Effective pressure extraction occurs by means of single bores. Pressure measurements are taken with a minimeter (measuring accuracy: 1/100 mm WS).

2.2.4.2. The intake nozzle, diameter 250 mm, mentioned above in 2.2.1., is provided for the limits of 1000 to 3000 cu m/hr. This permits measuring quantity of flow independently of the operating condition of the unit on the pressure side and corresponds to DIN 1952. The nozzle additionally was compared to the standard orifice in DIN 1952. At an operating temperature of 20° C and an air density of 1.2 kg/cu m, $Q=606\sqrt{p}$, in which Q is in cu m/hr and p in mm hg. Error is regularly below 3%. Measurement of pressure is likewise done with the Askaniaminimeter at an accuracy of 1/100 mm hg.

At a rate of flow of 995 cu m/hr, pressure on the input nozzle amounts to 2.7 mm WS, with a rate of flow of 3010 cu m/hr, it is 246 mm WS.

## 2.2.5. Visual Oil Thread Test

Theoretical observations and experimental tests show that small leaks on filter cells, which may have up to 22 sq m filter surface, may effect very small reductions of the total elimination rate. By means of the following method such leaks may be recognized quickly. The filter element to be tested is connected to the impure air diffuser, as described in 2.2.1., but the flange of the purified air diffuser is not used to hold it in place, instead a simple, flat frame is used (Figure 3). The visible purified air side, as well as frame, housing and packing of the "dust" filter type S are illuminated with a large light source (e.g. 500 W) and concentrated oil mist at slow velocity ($< 0.1$ cm/sec) is passed through the filter. Against a dark background (Figure 4) the smallest leaks become visible by the appearance of stray light hitting oil threads. The smallest micropores within the filter materials may be tolerated under certain circumstances, if the total does not fall below the required elimination rate. In practical use, these pores close up after a short period because of increased air permeability, and consequently increased "dust" supply, so that full effectiveness will be reached. Leaks at the frame or because of breaks in the cement used for tightening the frame as well as visible pores may lead to negative estimates.

## 2.3. Testing of Filter Material or Filter Element for Elimination Capacity (or Permeability) with Regard to Radioactively Indicated, Natural Atmospheric Aerosols.

### 2.3.1. General

Although the oil mist test method described in 2.2. permits recognition of all leaks as well as permeability maxima (or elimination rate minima) at particle size range 0.3 to 1$\mu$m, a series of gilter material exists whose maximum permeability is below particle size 0.3$\mu$m. To measure these properties of "dust" filters the following method, already reported in (5, 6, 7) was developed.

### 2.3.2. Structural Design of the Filter Test Instrument

The instrument is shown in Figure 5. It consists of a Chiron blower (2800 rpm; 0.33 kW, 25 c m/hr 440 mm WS), which sucks through a 1030 mm long pipe and 140 mm wide air space, then through a special clamping device which is behind the suction pipe, and blows over a flow measuring field into the open. A standard 18.5 mm orifice is used for rate of flow measurement according to DIN 1952, and the difference is measured with a micromanometer. Directly behind the blower is a pressure regulating valve to regulate the air quantities sucked through.

The special clamping device (Figure 6) consists of two pipe sections 77 mm long each, with inside diameter 140 mm and outside diameter 160 mm, between which the filter to be tested plus a support frame are clamped. Each insert also has outside connection which is attached evenly at five measuring locations at the circumference for measuring the static pressure. A filter probe for measuring radioactive "dusts" in front and behind the filter are led to each insert by means of a stuffing box. The two inserts together with ring with supporting frame and filter are under one control. By rotating a fixed worn gear, a barrel ring is rotated towards the blower which presses, over three rods fastened to it, the suction tube, stored on rollers, hard and evenly against the inserted sections, and results in air tight sealing.

Between 1 and 30 cu m air per hour may be sucked through the filter or filter material tested. Exhaust air from the instrument is blown to the outside through filters of special type S.

### 2.3.3. Preparation of Radioactively Indicated Aerosols (less than 0.3 $\mu$m diameters) for Use as Test Aerosols

The contents of one or several 25 liter washing flasks filled with prefiltered air, are pumped over a highly emanating radiothorium preparation (TH 228). By means of the prefiltering the air should be relatively free of all suspended particles greater than 0.3$\mu$m(5). A mixture of air, "dust" particles and Thorium emanation (Rn 220, Em 220) are obtained. When activity of the air in the flask is sufficient, inlet and outlet should be closed. Mixture of air, "dust" particles and Thorium emanation should be left alone for at least 10 minutes. During this time the thorium emanation will have disintegrated to 1% and the "dust" particles left in the air will be radioactively marked by the addition of Thorium B atoms formed.

By permitting water to run into the flask the radioactive "dust" -air mixture is compressed. It is mixed evenly with the air of the test instrument by being sent over a hemispherical probe, which has small outlets in all directions to the suction pipe.

### 2.3.4. Determination of Elimination Rate of Flow Through in Comparison to Radioactively Indicated Aerosols Greater than 0.3 $\mu$m in Diameter

The load of the material section to be tested must be equivalent to the load of the filter element. Two methods for determining elimination rate exist, both of which are equivalent with regard to accuracy. Choice of method depends on activity and radiation detection equipment available (counter tube, ionization chambers, their geometric dimensions and sensitivity). Essential for a decision is also whether measuring filters, whose elimination rate (or permeability) towards the aerosols here used is known well enough.

#### 2.3.4.1. The Direct Method

Starting from the consideration that elimination of "dust" filters of type S follows an exponential rule, the following relation may be expressed: If two test samples of filter materials $F_1$ and $F_2$, whose rate of elimination may be $\eta_1$ and $\eta_2$, are joined in series, and they are hit by air which contains short life radioactive "dusts", by means of a counter tube an activity of $N_{F1}$ is measured at filter $F_1$ and at the other $N_{F2}$. After fading of activity on the sample pieces the test is repeated, only in this case the filters are reversed. If the activities are appropriately marked $N'_{F2}$ and $N'_{F1}$, without knowing the impure air concentration, the following equation for elimination rate is found:

$$\eta_{F1} = \frac{N_{F1}\,N'_{F2} - N_{F2}\,N'_{F1}}{N_{F1}\,N'_{F2} + N_{F2}\,N'_{F2}}$$

$$\eta_{F2} = \frac{N_{F1}\,N'_{F2} - N_{F2}\,N'_{F1}}{N_{F1}\,N'_{F2} + N_{F1}\,N'_{F1}}$$

This test method has the great advantage of not being dependent on impure and purified air measurements and consequently remains free from errors of measuring and probe equipment as well as from those of undefined elimination rate of the dust measuring apparatus for the radioactive aerosols.

The interval for the two filters can be kept so small - practically to tenth millimeters - that a detectable error, because of partial elimination of the particles passed through the first filter, does not come into existence through diffusion or elective image force at the walls. The smaller

the material samples used, the larger are the deviations of $\eta_{F1}$ and $\eta_{F2}$, since the elimination rate of a filter material, as a result of density and thickness fluctuations are not the same at all surface areas. The larger and more uniform the material samples can be chosen, the more nearly $\eta_{F1}$ + $\eta_{F2}$ approach each other. If $\eta_{F1} = \eta_{F2} = \eta$, the formula is simplified to

$$\eta = 1 - \frac{N_{F2}}{N_{F1}} .$$

The activities of the sample sections are carefully determined in a proportional counter, a flow counter or an ionization chamber of corresponding size (Figure 7). Before measuring activity, radioactive equilibrium should be awaited between Thorium B (Pb 212) and its metabolon. This may take 6 hours or more.

2.3.4.2. Indirect Method

A sample section of the filter material or the filter itself is placed in the instrument as described in 2.3.2. The probes found in the inserts are covered with a filter material, whose elimination rate for the test aerosol used and whose flow velocity must be exactly known. During the entire contact of the test filter with the radioactive test aerosol, sample of flow are removed simultaneously by the impure and purified air probes. Accuracy in measurement of the volume of the partial volume sucked off is of major importance. Two large Mariott flasks which are connected by a hose to a filter probe each may be recognized to the right in Figure 5.

The partial flow quantities, removed by the filter probes, for determination of radioactive "dust" before and after the filter to be tested, is determined by measurement of the volume of the discharge water. The determination of radioactive "dust" concentration on impure and purified air is made as described in 2.3.4.1. The devices for measuring emission may be of smaller dimensions relative to the smaller diameter of the measuring filters.

2.4. Testing of the Filter Material or Filter Element for Elimination Capacity (or Permeability) with Regard to the Finest, Freshly Obtained Quartz Dust of 0.5-10 $\mu$m diameter Particle Size

2.4.1. Assumptions

"Dust" filters, whose construction gives doubt as to the elimination capacity with increasing "dust" accumulation (e.g. fiber or paper filters with extremely high flow velocities, above 1 m/sec. or of smaller inertial stability) should be partially or totally subjected to additional testing with quartz dust.

### 2.4.2. Structural Design of the Quartz Dust Instrument

The installation has been described variously (8, 9) so that only a brief description follows here (Figure 8). A speed regulated blower sucks air through test chamber K, which is connected to two 45° diffusers D, each containing four filters, through filter F, a measuring duct VI, flow stages V, II, I, and a sedimentation chamber W. The other flow sections are closed off by slider bar S. The outlet of a continuously operating tube mill, the inlet opening of which is connected to an intake flue through a heating box, exhausts in sedimentation chamber W. The tube mill has an inside diameter of 300 mm, a length of 1000 mm and is capable of 60 rpm. Steel balls are used as grinding elements. Standard cement sand #1 (fine) is continuously fed to the mill in quantities larger than it can grind. For this reason the mill spills into separator W. The size of the separator is 1000 X 1000 X 2000 mm, diameter of the ducts is 300 X 300 mm, that of the measuring duct VI is 500 X 500 mm. Floor area of the actual test chamber K is 1410 X 1410 mm, its height 1000 mm. Volume of chamber K including diffusers D amounts to 3.25 cu m. The filter sections to be tested are placed in a special mounting in the test chamber and are tested by means of the blower.

Measuring of the flow rate is handled according to the weight limits by standard diaphragms, flow meters or other commercial apparatus. Error amounts to less than 6% in any case. Directly at the filter mounting is a sampling device to measure impure air concentration in the chamber.

### 2.4.3. Preparation of the Test Dust

Since more sand is fed to the tube mill than it can grind and it "overflows", equilibrium with regard to particle sizes in the sand in the mill occurs after a single run. The air streaming through the mill transports the most finely ground dust particles to sedimentation chamber W. Blower G is regulated so that after two siftings in W and diffuser D, a quartz test dust results in which 80% of the particles are of diameter 0.5 - 2 $\mu$m, 15-17% 2-5 $\mu$m and the remainder 5-10 $\mu$m. Particle size and concentration are determined during each test by a therman precipitation sample. Particle size concentration amounts to about 12000-18000 particles/cu cm, gravimetric concentration to 120 mg/m$^3$.

### 2.4.4. Measurement of Elimination Rate (or Permeability)

The Tyndallometer (see 2.2.3.) with a 30 Watt lamp is used to determine impure and purified air concentrations. The special filter mounting as well as the impure air probe (see 2.4.2.) are connected by a three-way valve to the tyndallometer, to which the flow through the instrument and blower are attached. By varying the 3-way valve impure and purified air concentrations may be measured alternately and the elimination rate (permeability) determined every minute of the test period. The test period lasts a maximum of 60 minutes. It may be broken off prior to this if maximum flow resistance is reached.

2.4.5. Measurement of Flow Resistance

Behind the clamped filter the filter mountings are connected to the probe, whose circumference is evenly bored, and which joins a circular duct. Depending on measuring limits required, the difference in pressure (pressure behind the filter minus pressure on the free flow against the filter surface) is measured with an inclined tube, U-tube, or mercury manometer.

3. Test Standards and Evaluation of Filters

3.1. Limitations and Purpose

The outlines given refer mainly to testing of "dust" filters, in particular to those of special type S. These directions, because of their application, denote completely different types of test aerosols, and because of their employment, entirely different measuring methods (optical scatter light and pure activity measurements in contrast to gravimetric dust concentration measurements) then given by (1). The instructions given for "dust" filters and special type S "dust" filters should give the user assurance that proper application will result in minimum efficiency rates for the most important particle sizes. The figures given below apply to elimination and permeability only for the test methods given here and the test instruments used therewith.

3.2. Testing Elimination Rate in Relation to Oil Mists of 0.3 - 1$\mu$m Diameter

Every "dust" filter being tested is tested as a complete filter by the installation described in 2.2, and by the method of 2.2.3. is tested for 20 minutes for its elimination capacity or permeability.

Following this the oil thread test described in 2.2.6. is carried out.

If the elimination rate during the entire test period exceed (99.7 $\pm$ 0.02)% (permeability less than (0.30 $\pm$ 0.02)%, and the oil thread test show no leak in housing, frame or cement, and no visual pores are present in the filter material, the filter may be designated as "dust" filter special type S, if however, the requirements of 3.4 also are met. Filters, whose elimination rate exceed (85.00 $\pm$ 0.05)% but is below 99.7% may be designated as "dust" filters.

3.3. Flow Resistance and Air Permeability

Flow resistance at a given amount of flow is measured according to 2.2.4. Air flow at 10-20 mm WS flow resistance for the clean, non-dusty filter material in cu m/hr for each sq m of filter material surface is tested additionally. These instructions take the importance of paper and fiber technical phase into consideration.

## 3.4. Testing of Elimination Rate Towards Radioactively Indicated Natural Atmospheric Aerosols, Diameters Smaller than 0.3 $\mu$m.

In connection with the oil mist test a new non-dusty filter material sample or a new filter element is tested according to instrument and method described in 2.3. A total of at least 300 sq cm filter surface, divided into two equal samples, must be tested. The average elimination rate for "dust" filters special type S should be (99.95 ± 0.02)% (permeability less than (0.05 ± 0.02)%, the smallest elimination rate no less than (99.90 ± 0.02)%, and permeability no less than (0.10 ± 0.02)%. Filters, whose elimination rate exceeds 70% (permeability less than 30%, but less than 99.95% (permeability 0.05%), are designated "dust" filters.

## 3.5 Testing of Elimination Rate Towards Freshly Obtained Quartz Dust, Diameter 0.5 - 10 $\mu$m

Filters whose properties may deteriorate with increasing dust accumulation (according to 2.4.1.) should additionally be tested by the method and instrument of 2.4. Since it is not possible to increase impure air concentration in the quartz apparatus without changing particle size distribution, the measuring accuracy is smaller in comparison to other test methods. It is required therefore, that the material sample of the "dust" filter special type S does not fall below 99% in elimination rate (or exceed 1% permeability) in the test period. The specific accumulated dust quantity (g/sq m) and flow resistance are given. Filters, whose elimination rate exceeds 95%, but falls below 99% are designated "dust" filters.

## 3.6 Changes

Small structural changes in apparatus and changes in concentration of test dust are permissible, as long as particle size distribution of the aerosols are not essentially changed.

## 4. Summary

Good "Dust" filters and "dust" filters special type S must have the following minimum elimination rate toward the following aerosols:

| Filter | Elimination Rate | | | |
|---|---|---|---|---|
| | Oil Mist Diameter <1 μm Maximum d.T. 0.3-0.5 μm Measurement: Max. Scatter light | Radioactively indicated aerosol diameter < 0.3 μm Measurement: activities | Quartz dust diameter < 10 μm Max. d.T. 0.5-2 μm Measurement: Max. Scatter light | Oil Thread test |
| "Dust" Filter Special Type S | > (99.70 ± 0.02)% | $\bar{\eta}$ > (99.95 ± 0.02)% $\eta$ min > (99.90 ± 0.02)% | Only in special cases always > 99% | Must prove that no leaks and visually recognized pores are present |
| "Dust" Filter | >(85.00 ± 0.05)% | > (70.00 ± 0.05)% | Always > 95% | Only in special cases |

## Bibliography and Footnotes


1. Richtlinien zur Pruefung von Filtern fuer die Lueftungs- und Klimatechnik /Guide Lines for Testing Filters for the Ventilation and Air-conditioning Industry7, published by the Dust Research Institute of the Main Association of the Industrial Labor Unions, Inc.

2. See also Richtlinien fuer Leistungsversuche an Entstaubern /Guide Lines for Performance Tests of Dust Collectors7, published by Dust Technology Committee of the VDI /German Engineering Association7

3. See DIN /German Industrial Standards7 1946, Sheet 1, "Ventilation of Hospitals."

4. See 11th and 15th report of the German Committee on Breathing Protection Equipment.

5. Hasenclever, D., "The Use of Radioactive Indicator Substances in Solving Dust Problems," Staub, No. 44, 1956, pages 159-173.

6. Hasenclever, D., "Testing of Filters for Separation of Radioactive Aerosols," Staub, Vol 19, No 2, 1959, pages 37-43.

7. Hasenclever, D., "Methods of Testing High-quality Suspended Substance Filters for the Separation of Radioactive Aerosols and for Personal Protection -- Lessons Learned and Outlook," Staub, Vol 21, No 7, 1961, pages 281-285.

8. Hasenclever, D., "New Equipment for Testing Dust Masks and Protective Devices for Sandblasting," Staub, No 25, 1951, pages 172-181.

9. Hasenclever, D., "Investigations on the Suitability of Various Dust Measurement Equipment for the Operational Measurement of Mineral Dust in Plants," Staub, No 41, 1955, pages 388-435.

## FIGURE APPENDIX

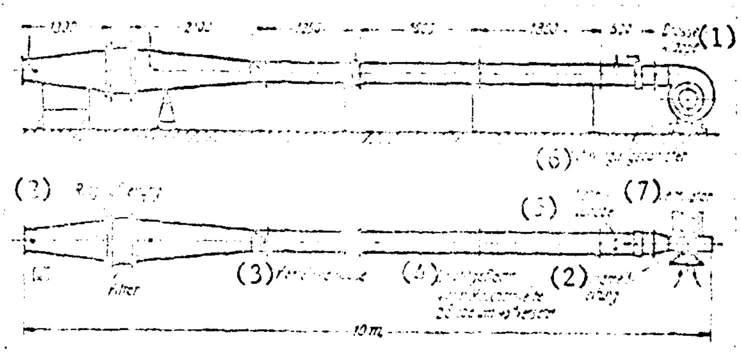


Figure 1. Testing device for suspended material filters and for suspended material filters of special type S.
Legend: (1) butterfly valve; (2) ring measurement line; (3) quadrant nozzle; (4) wire mesh, 4 mm mesh width, two screens at 45° angle; (5) fog injection; (6) vibration absorber; (7) fan.

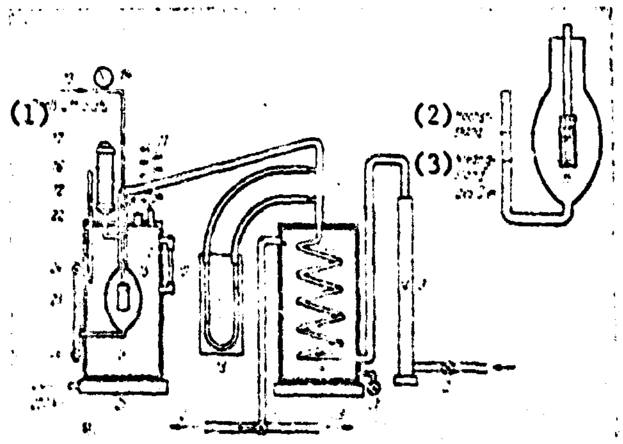


Figure 2. Diagram of fog generator.
Legend: (1) compressed air, 5 ato; (2) maximum level; (3) low oil level.

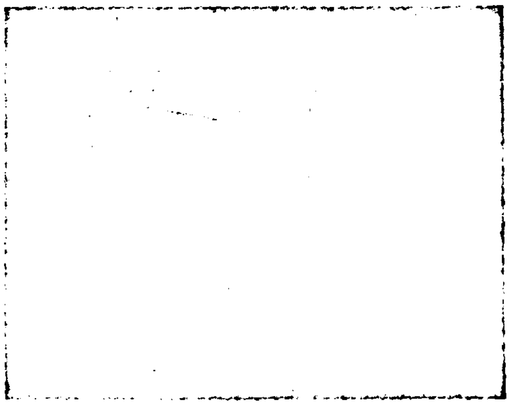

Figure 3. Connection of suspended materials filter to crude air diffuser for oil thread test.

Figure 4. Emergence of "oil thread" indicates impermeability flaws when oil fog is slowly piped through



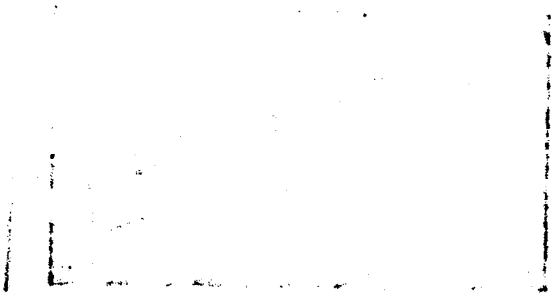

Figure 5. Testing apparatus for filters, using radioactive aerosols.

Figure 6. Filter attachment device.



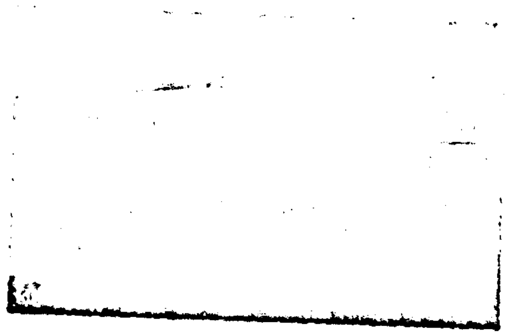

Figure 7. Ionization chamber with removable bottom (left) for measuring activity of filters for diameter of up to 160 mm. Right: vibration condensator measurement amplifier.

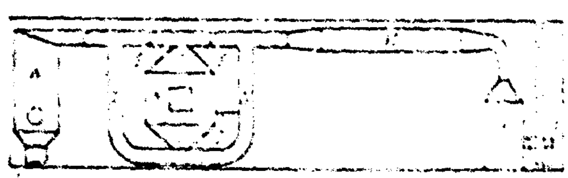

Figure 8. Quartz dust equipment diagram
(W -- sifter; K -- testing chamber; D -- diffuser;
S -- slider; F -- Filter; G -- blower.)